(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 December 2000 (21.12.2000)

PCT

(10) International Publication Number
WO 00/77566 A1

(51) International Patent Classification[7]: G02F 1/1335

(21) International Application Number: PCT/EP00/05588

(22) International Filing Date: 13 June 2000 (13.06.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/140,669 14 June 1999 (14.06.1999) US

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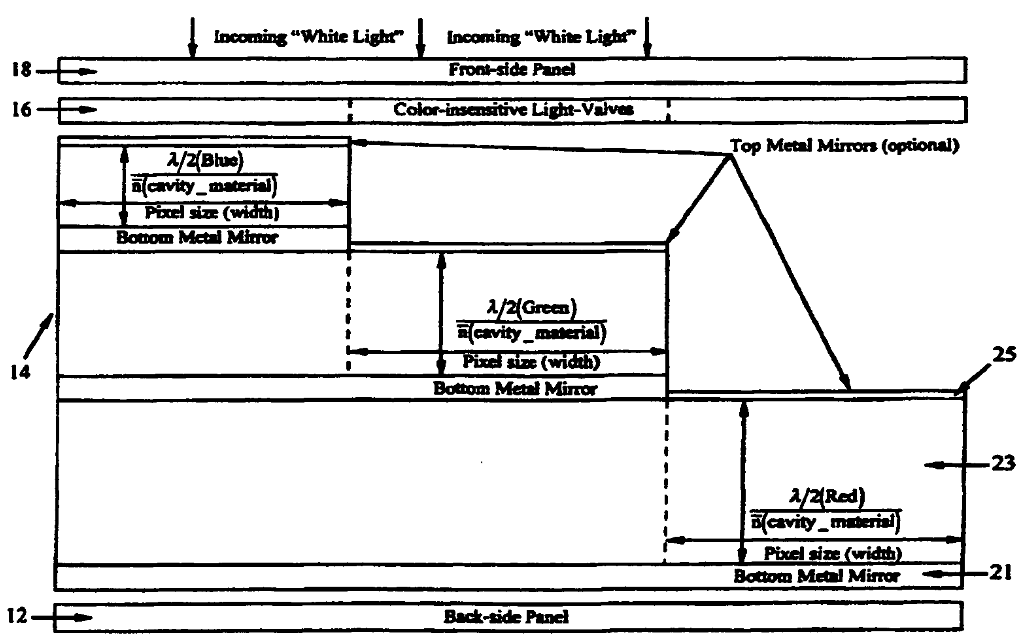
(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*
— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: DISPLAY OR IMAGER DEVICE WITH INTEGRATED WAVELENGTH FILTER



(57) Abstract: The addressing matrix (12) of the device has an integrated photonic wavelength filter structure (14) positioned on one face thereof such that it is located between the addressing matrix and the light-valve means of the display. For each color wavelength, the photonic wavelength filter structure includes a stack of microcavity material having a substantially large refractive index.

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DISPLAY OR IMAGER DEVICE WITH INTEGRATED WAVELENGTH FILTER

Field of the Invention

The present invention relates generally to color display and imager apparatus and more particularly to the fabrication of a filter structure usable in flat panel displays and image capture devices.

Background of the Invention

In the field of Flat-Panel Displays (FPDs), Liquid Crystal Displays (LCDs) have the commercial lead over all other competing technologies, like Plasma Displays, Light Emitting Diode (LED) Displays, Field Emission Displays, etc.

However, it is recognized that further progress is required in some of aspects of FPDs, in order to improve their overall performance. One such component, is the formation of color filters. This difficulty is also encountered in the making of Image Capture Devices (Imagers), like Charged Coupled Devices (CCDs) and Complementary Metal Oxide Semiconductor (CMOS) Imagers, which are the most widely used types of Imagers.

For direct view, passive (no light-emission) color displays, color filters of the three primary additive colors (Red, Green, Blue - RGB) are provided on the panels themselves, through the arrangement of color dye elements on the front-side panel (which is transparent). Each color dye element must be aligned with the respective switching element, separately fabricated on the backside panel. The switching element is part of an "addressing matrix", that can be passive or active.

Passive FPDs, like LCDs, do not emit light by themselves, and illumination is provided from backside or frontside, for transmission or reflection displays, respectively.

Imagers, by nature, are also passive devices. Because CCDs and CMOS Imagers, are made with homojunctions, the band-gap is not engineered, and therefore light absorption cannot be tuned (at the absorbing medium) for any particular wavelength.

As it is an intrinsically medium, a passive display or an imager offers advantages from the power consumption standpoint. On the other hand, since no light of any particular wavelength is emitted, either to project an image (passive FPDs) or to capture one (Imagers), some sort of color filtering (of the white light which or impinges upon them) is needed to make color displays and cameras.

For projection type of displays, color output can be provided by optical setups that cannot be integrated, like a simple rotating color wheel in front of a single small panel, or by overlaying the images of three different panels, each with a filter of one of the three primary

additive colors. In the last case, a more complicated optical set-up is needed, where mechanical alignment of the three images projected by each single primary additive color panel, is critical for image quality.

Quite similar setups are possible, and in fact used, with Imagers in order to improve the resolution and other features. With a single photo-detector that has three color filters, simplicity, size and cost optimized. For improved resolution, beam splitters are used to provide the same image to three different detectors, each with a single color filter for each of the primary additive colors. "3-Chip" cameras are a common architecture to deliver the best performance, for the professional market and for the high-end segment of the consumer electronics market.

For Imagers, higher resolution, typically means reduced pixel sizes, and smaller active areas for light absorption. Therefore a trade-off between the signal to noise ratio, read-out speed, and signal intensity has to be made. These conflicting requirements lead to compromised performance that can only be satisfied with "3-Chip" solutions, having 1 chip assigned for each of the primary colors.

There are important technological issues with color dye materials, which ultimately can limit the progress towards higher resolution, better performing Displays and Imagers:

- The amount of light which is absorbed in the color dye itself.
- The cost of better color dye, with less light absorption.
- The toxic properties of more transparent color dye materials.
- Scalability of the fabrication methods of these color filters due to alignment problems.
- The color dye cannot withstand high temperatures, which are necessary to reduce the resistivity of *ITO* (relevant for LCDs), and causes integration problems with CMOS (important for Imagers).

It has been well known in the microelectronics industry, almost since its beginning, that when thin SiO_2 (and Si_3N_4) films are formed on a polished silicon surface, the color changes with the thickness. There exist tables relating the color to film thickness ("Physics of Semiconductor Devices", S. M. Sze, 2nd Edition 1981, Wiley & Sons).

This effect appears because for the visible range of electromagnetic radiation, the silicon polished wafer has mirror-like properties. The SiO_2 film, having refraction index significantly different than the silicon wafer and than from air, acts like optical cavity, enhancing a single wavelength (or narrow range of wavelengths) while dampening all other "colors".

The optimum size for a cavity made of SiO_2, is given by the formula below, where the SiO_2 film thickness, divided by half of the wavelength of the photons in SiO_2 equals m,

where m is an integer larger than 1. When $m = 1$, the effect is maximized, and that particular wavelength is strongly enhanced.

$$\frac{thickness(SiO_2)}{\lambda(SiO_2)/2} = m$$

with

$$\lambda(SiO_2) = \frac{\lambda(Vacuum)}{\bar{n}}$$

and $\bar{n}$ is the index of refraction of the medium.

This kind of filter is widely used in spectroscopic measurements. High performance Fabry-Perot cavities include high reflectivity metallic mirrors and cavity materials with large index of refraction, in order to maximize reflection.

The experimental evidence, and the solid theoretical foundation which explains the microcavity interferometers, are the basis of the present invention.

Summary of the Invention

It is therefore an object of the present invention to provide a novel and high efficiency wavelength filter structure usable in Flat-Panel Displays (FPDs) and Image Capture Devices (Imagers).

Another object of this invention is to provide a method for the fabrication of addressing matrices for Flat Panel Displays and Imagers, which are integrated with a photonic wavelength filter.

An addressing matrix for flat panel color display or imaging device or the like has a photonic wavelength filter structure positioned on one face thereof such that it is located between the addressing matrix panel and the light-valve means of the color device.

The photonic wavelength filter structure includes, for each color wavelength, a stack of microcavity films having a specific thickness or width and/or a substantially refractive index. The stack of microcavity films for the different color pixels can be positioned side-by-side or on top of each other.

Unlike conventional color dye filters, the wavelength filter structure according to the invention can be made integrated with the addressing matrix (whether active or passive) on the back panel of the display. Therefore, alignment between the front-side and back-side panels is no longer required, and will no longer be a barrier for further pixel scaling (higher resolution).

The advantages of the invention can be summarized as follows:

- Dispenses from color dye and avoids all the issues related with its use in the fabrication of Flat-Panel Displays and Imagers.

- Independent of overall panel size, or shape.
- Independent of the mechanical substrate: Glass, Plastic, etc.
- Independent of addressing mode: Passive- or Active-Matrix.
- Independent of electronic substrate: amorphous, poly or single crystal.
- Independent of the device architecture: Thin Film Transistors, standard Planar MOSFETs, Vertical MOSFETs, etc.
- Fabrication can be integrated with addressing-matrix.
- No alignment to be made between front- and back-panels. Therefore alignment is no longer an issue when scaling to smaller pixel sizes and/or higher pixel densities.
- Arbitrary choice of primary colors by selecting the appropriate optical path length (film thickness and refraction index), rather than employing different materials for each different color.
- Materials and processes compatible with microelectronics can be used.
- Color dye no longer set processing constrains on the processing of the conductive transparent front-side electrodes (typically made with *ITO*). Therefore, by making the electrodes thicker and deposited at higher temperatures, it is possible to lower the resistivity of these electrodes. (This issue is only relevant for certain types of "Light-Valves").

Exemplary embodiments for the filter structure of the invention and the method of fabricating same will be described in detail in the following, reference being had to the accompanying drawings.

Brief Description of the Drawings

FIG. 1 is an exploded schematic view of a flat panel display incorporating a first embodiment of the filter structure according to the invention;

FIG. 2 is a schematic representation of a variation of the filter structure of FIG. 1;

FIG. 3 is a schematic representation of a second of the filter structure according to the invention;

FIG. 4 is a schematic representation of a variation of the filter structure of FIG. 3;

FIG. 5A to FIG. 5D illustrate the fabrication of the filter structure shown in FIG. 1;

FIG. 6A to FIG. 6D illustrate the fabrication of the filter structure shown in FIG. 2;

FIG. 7 A to FIG.7C illustrate the fabrication of the filter structure shown in FIG. 3;

FIG. 8 represents a variation of the filter structure shown in FIG. 4;

Detailed Description of the Invention

Referring to FIG. 1, there is shown how a photonic wavelength filter structure according to the invention is integrated in the addressing matrix of a flat panel display. The components of the display are identified as follows: 12 designates the back panel with the addressing matrix, 14 designates a filter structure according to the invention, 16 designates light valves and 18 designates the front-side panel. The filter structure 14 comprises a stack of films for each primary color. Each stack is comprised of a bottom metal mirror 21 and an optical cavity layer 23. A metal mirror 25 can be placed on top of the stack. Such stacks are compatible with metallization processes used in microelectronics and are suitable for integration on the back-panel with the addressing matrix of any Flat-Panel Display.

Filters for different wavelengths (colors) are obtained by providing different optical path lengths, that is, by fabricating cavities with different film thicknesses and/or different refractive indices. The filters for the different colors can be implemented side by side as shown in FIG. 1 or on top of each other as shown in FIG. 2.

Cavities for the three additive primary colors Red, Green and Blue (R, G, B), should have the following properties (the exact wavelengths for the different colors are not universal):

Thickness of the cavity material for Red color filter = $(700nm / 2) / \bar{n}$.

Thickness of the cavity material for Green color filter = $(550nm / 2) / \bar{n}$.

Thickness of the cavity material for Blue color filter = $(400nm / 2) / \bar{n}$.

Materials suitable for optical cavities and widely used in microelectronics are for example, silicon dioxide (SiO_2) and silicon nitride (Si_3N_4). Their indices of refraction are $\bar{n}(SiO_2) = 1.46$, and $\bar{n}(Si_3N_4) = 2.05$.

Diamond can be an even better material for the optical cavity due to its larger index of refraction (2.45). Although a non-standard material in today's microelectronics, it should not present insurmountable barriers with the appropriate process flow.

The Photonic Wavelength Filter structure described above is pixel-specific, and applicable to any type of Reflection-type Display: projection or direct view, with passive or active addressing, and on amorphous, poly or crystalline substrates. In Reflection-type Display, the color filters are positioned in between the "addressing-matrix" and the "light-valve".

The key feature in the structure is the presence of the optical cavity between two surfaces with sufficiently different refraction indices. The larger this difference, the stronger the reflection is. In order to optimize this effect, the quality of the interfaces should also be high (small surface roughness), to maximize interference effects, and prevent losses due to scattering at the interfaces.

Metals like aluminum and silver provide a nearly constant reflectivity for the entire range of visible wavelengths. Therefore, these metallic mirrors are taken to be wavelength-independent (for that range of wavelengths). One drawback of metallic mirrors is that they absorb a fraction of the light traveling through them. There is a tradeoff between the reflectivity and the absorption of metallic mirrors.

Fixed-wavelength Fabry-Perot interferometers have been demonstrated in silicon-compatible technology ("High-Selectivity Single-Chip Spectrometer for Operation at Visible Wavelengths", J. H. Correia, M. Bartek, R. F. Wolfenbutte, Technical Digest of the IEDM, 1998). Filters for several different wavelengths were fabricated on the same silicon wafer.

The above-mentioned work proves that such concept not only works, but that it can also be implemented with technology compatible with CMOS. This work aimed at instrumentation for spectroscopic analysis. The filters were "discrete" components, and not elements in a matrix covering the full surface of the silicon wafer, which is absolutely necessary for displays. Application of the filters as color filters for Flat Panel Displays were not mentioned or even suggested in said reference. The embodiment shown in FIGS. 1A and 1B has the following specific advantages: it is very simple to fabricate due to color-independence of the mirrors, and the filter height / thickness roughly corresponds to the cavity length.

Metallic mirrors positioned at the top and bottom of the microcavity however have a big drawback. The top mirror, although sharply enhancing the reflectivity at that surface, also absorbs light despite of being a thin film. However, it is possible to have high reflectivity surfaces without light absorption when the metallic mirrors are replaced by dielectric mirrors, of which the Distributed Bragg Reflector (DBR) is the simplest and best known example.

For already many years, Vertical Cavity Semiconductor Lasers have made use of Distributed Bragg Reflectors. DBRs are made with alternating layers of semiconductor or dielectric materials with indices of refraction as different as possible. With appropriate design of the sequence and thickness of those dielectric layers, high reflectivity without absorption is possible. The non-absorption is for photons with energies smaller than the band-gap of the semiconductor or dielectric materials used.

DBRs are quite different from metal mirrors, not just by the fact of not absorbing electromagnetic radiation, but also because they are very wavelength-sensitive and very directional. In fact, a DBR is transparent to all wavelengths other than the one it was designed to reflect and a small interval of wavelengths centered around it.

Owing to their property of being sensitive to the wavelength, DBRs can serve simultaneously as mirrors and filters, thereby considerably simplifying the requirements to

make color filters because it becomes unnecessary to fabricate a microcavity for each wavelength to be filtered.

Assuming that the filters for all wavelengths use the same dielectric materials, and that these materials have optical parameters that remain nearly constant for the range of wavelengths in question, then designing a DBR for a particular wavelength, amounts just to specify the number of pairs of dielectric layers and the precise thickness of each layer.

It should be perfectly feasible to fabricate "color filters" for FPDs, using such well known and commonly used materials (in silicon technology) like SiO_2 and Si_3N_4, which have very wide band-gaps, which are far larger than the energy of photons in the visible range.

As DBRs are very directional, that is, reflectivity is very dependent on the angle of incidence upon the dielectric mirrors, this makes "regular" DBRs very problematic for color filters for Flat Panel Displays, where poor viewing angles have plagued the mainstream technology (LCDs) up to the present day.

However, recent developments at the theoretical and experimental level can solve this limitation of DBRs. It has been discovered that under certain circumstances, it is possible to make the DBRs with properties such that they can become a "One-Dimensional Photonic Band-Gap" (1D-PBG) material having the property of nearly perfect reflection for a very narrow band of wavelengths and of being transparent to all others, and all this with an extremely wide viewing angle. This development solves the problem of the "directionality" of the reflected waves, and from the optical point of view, makes these 1D-PBG DBRs an extremely good solution as color filters for Flat Panel Displays and Imagers. What is required for their application as color filters in Flat-Panel Displays is the fabrication of filters for three primary colors (typically R, G, B), having narrow interval of wavelengths (centered around each of those primary colors) for which light is reflected. This narrow interval is a requirement for good "spectral purity" of these color filters. The three filters can be stacked upon each other as they are transparent to all wavelengths other than the one that each of them is supposed to reflect and be a perfect mirror to.

If it turns out that amorphous and poly-crystalline materials like SiO_2 and Si_3N_4 (or others equally well known and used in microelectronics), are not "good enough" for the fabrication of these special 1D-PBG DBRs, then it may be suitable to use insulators which are known to be epitaxially compatible with silicon. There are very wide Band-Gap insulator materials like Al_2O_3 (Sapphire), CaF_2, CdF_2, CeO_2. These have been demonstrated to deposit on silicon with very high epitaxial quality (given the appropriate set of experimental conditions), and stacks with multiple layers of these materials and silicon have also been fabricated.

FIGS. 3 and 4 schematically represent two implements with dielectric mirrors. In FIG. 3, the mirrors/filters for the different colors are made side-by-side. Because the DBRs

are transparent to the "non-resonant" wavelength, there is a need to have an absorbing layer 31 at the back of each reflector 33 (rather than a metal mirror which would reflect back all wavelengths). For example, silicon and silicon-germanium films, can be efficient absorbers of electromagnetic radiation in the visible range. In the variation shown in FIG. 4, the mirrors/filters 35, 37, 39 are positioned on top of each other, with only one photon-absorbing layer 31 positioned at the bottom of the stack of 3 DBRs. This implementation requires a wavelength-sensitive "Light-Valve". Such a wavelength-sensitive light-valve can be implemented directly on top of the reflectors as shown at 40 in FIG. 8.

The wavelength filter structure with dielectric mirrors as described in the foregoing has specific advantages that can be summarized as follows:

- Absence of absorption enables extremely high reflectivity values.

-Freedom in choosing wide range of reflectivity values for each reflector.

-Reflector layers do not have be conductive, thereby giving extra freedom in choosing materials.

-Gain in process simplification and a factor of 3 in area and/or resolution and/or signal-to-noise ratio, when positioning the 3 primary color filters on top of each other, possible with wavelength-selective light-valves.

The method of realizing an addressing matrix with integrated wavelength filter structure according to the invention is described herein after with reference to FIGS. 5 to 8 which illustrate exemplary process flows for both embodiments set out in the foregoing. All the process flows are based on the assumption that the substrate is planarized (for example with an insulator layer such as SiO_2).

FIGS. 5 and 6 illustrate two process flows for the fabrication of a wavelength filter structure with metal mirrors.

Process Flow #1

The three different optical path lengths are achieved by:

- Deposition of bottom metallic mirror.
- Deposition of dielectric film or film stack with total thickness corresponding to cavity length required for the longest wavelength to be filtered (Red color).
- First patterned etch of cavity material, to match cavity length required for the Green color filter.
- Second patterned etch, of cavity material, to match cavity length required for the Blue color filter.
- Optional deposition of a very thin metal film as the top mirror for all cavities.

This process can be implemented using the following steps:

FIG. 5A:

1) Deposition (typically PVD) of metal film (Al or Ag).

2) Deposition (typically Plasma CVD) of dielectric film(s), for example Si_3N_4.

FIG. 5B:

3) Lithography: Mask #1: Protect Red pixels.

4) Controlled etch (wet or dry) of Si_3N_4 layer, stopping when remaining thickness is suitable for Green color filter. An ultra-thin film of a different material (like $SiON$ for example) can be inserted during the deposition of the cavity material, as a marker layer to reliably stop the etch.

5) Photo-resist strip + clean..

FIG. 5C:

6) Lithography: Mask #2: Protect Red and Green pixels.

7) Controlled etch (wet or dry) of Si_3N_4 layer, stopping when remaining thickness is suitable for Blue color filter. An ultra-thin film of a different material (like $SiON$ for example) can be inserted during the deposition of the cavity material, as a marker layer to reliably stop the etch.

8) Photo-resist strip + clean.

FIG. 5D:

9) Optional deposition (typically PVD) of a thin metal film as top mirror (Al or Ag for example).

Process Flow #2

The three different optical path lengths are achieved by:

- Deposition of metallic mirror under the cavity for the Red color.
- Deposition of dielectric film with thickness corresponding to cavity of Red filter.
- Deposition of metallic mirror under the cavity for Green color.
- Deposition of dielectric film with thickness corresponding to cavity of Green filter.
- Deposition of metallic mirror under the cavity for Blue color.
- Deposition of dielectric film with thickness corresponding to cavity of Blue filter.
- First patterned etch of cavity material and bottom metal mirror for Blue color.
- Second patterned etch of cavity material and bottom metal mirror for Green color.
- Optional deposition of a very thin metal film as the top mirror for all cavities.

This method can be implemented using the following steps:

FIG. 6A

1) Deposition (typically PVD) of metal film (Al or Ag), to be the mirror for the Red color filter.

2) Deposition (typically CVD) of dielectric film(s) for cavity of Red filter (for example Si_3N_4).

3) Deposition (typically PVD) of metal film (Al or Ag), to be the mirror for the Green color filter.

4) Deposition (typically CVD) of dielectric film(s) for cavity of Green filter (for example Si_3N_4).

5) Deposition (typically PVD) of metal film (Al or Ag), to be the mirror for the Blue color filter.

6) Deposition (typically CVD) of dielectric film(s) for cavity of Blue filter (for example Si_3N_4).

FIG. 6B

7) Lithography: Mask #1: Protect Blue pixels.

8) Controlled etch (wet or dry) of cavity and bottom mirror films for Blue filter, stopping on the surface of the cavity material for the Green color filter.

9) Photo-resist strip + clean.

FIG. 6C

10) Lithography: Mask #2: Protect Blue and Green pixels.

11) Controlled etch (wet or dry) of cavity and bottom mirror films for Green filter, stopping on the surface of the cavity material for the Red color filter.

12) Photo-resist strip + clean.

FIG. 6D

13 Optional deposition (typically PVD) of a thin metal film as top mirror (Al or Ag for example).

Referring now to FIGS. 7 and 8, there is illustrated two process flows for the fabrication of a wavelength filter structure with dielectric mirrors, using one-dimensional photonic band-gap DBRs (Distributed Bragg Reflectors). As noted above herein, the substrate is assumed to be planarized (e.g. with an insulator layer such as SiO_2).

Process Flow #1

The three different optical path lengths are achieved by:

- Deposition of bottom photon-absorbing film under the Red color mirror/filter.
- Deposition of stack of dielectric film to make the Red color mirror/filter DBR).
- Deposition of middle photon-absorbing film under the Green color mirror/filter.
- Deposition of stack of dielectric film to make the Green color mirror/filter (DBR).
- Deposition of top photon-absorbing film under the Blue color mirror/filter.
- Deposition of stack of dielectric film to make the Blue color mirror/filter (DBR).
- First patterned etch of top DBR (for Blue color) and top photon-absorbing film.

- Second patterned etch of middle DBR (for Green color) and middle photon-absorbing film.

This method can be implemented using the following steps:

FIG. 7A

1) Deposition (for example CVD) of photon-absorbing film.

2) Deposition (for example CVD) of DBR for Red color.

3) Deposition (for example CVD) of photon-absorbing film.

4) Deposition (for example CVD) of DBR for Green color.

5) Deposition (for example CVD) of photon-absorbing film.

6) Deposition (for example CVD) of DBR for Blue color.

FIG. 7B

7) <u>Lithography: Mask #1</u>: protect DBR layers for Blue color with resist.

8) Etch (wet or dry) of DBR for Blue and photon-absorbing films, stopping on the DBR for Green.

9) Photo-resist strip + clean.

FIG. 7C

7) <u>Lithography: Mask #2</u>: protect DBR layers for Blue & Green colors with resist.

8) Etch (wet or dry) of DBR for Green and photon-absorbing films, stopping on the DBR for Red.

9) Photo-resist strip + clean.

<u>Process Flow #2</u>

The 3 different optical path lengths are achieved using the following steps (FIG. 8):

- Deposition (e.g. CVD) of bottom photon-absorbing film (e.g. a photodetector, like imager or solar cell),
- Deposition of stack of dielectric films to make the mirror/filter (DBR) for Red color.
- Deposition of stack of dielectric films to make the mirror/filter (DBR) for Green color
- Deposition of stack of dielectric films to make the mirror/filter (DBR) for Blue color
- Formation of wavelength-selective light-valves.

Claims

1. A flat panel color display or imaging device or the like comprising a back panel with an addressing matrix (12), light-valve means (16) and a front-side panel (18), wherein the addressing matrix panel (12) has a photonic wavelength filter structure (14) positioned on one face thereof such that it is located between the addressing matrix and the light-valve means.

2. A flat panel device as claimed in claim 1, wherein the photonic wavelength filter structure (14) includes, for each color wavelength, a stack of microcavity material having a substantially large refractive index.

3. A flat panel device as claimed in claim 2, wherein the stack of microcavity material comprises at least one optical cavity film (23) positioned on a bottom metal mirror plate (21).

4. A flat panel device as claimed in claim 3, wherein said at least one optical cavity film has a specific thickness for each color wavelength, and wherein the stack for the different color pixels are positioned side-by-side.

5. A flat panel device as claimed in claim 2, wherein said at least one optical cavity film has a specific width for each color wavelength and wherein the stack for the different color wavelengths are positioned on top of each other, each stack extending such that the different color pixels are side-by-side.

6. A flat panel device as claimed in either of the preceding claims, wherein each stack of microcavity material has a metal mirror plate (25) positioned on top thereof.

7. A flat panel device as claimed in claim 2, wherein the stack of microcavity material (17) comprises a stack of a light absorbing layer (31) and at least one wavelength-selective photonic band-gap reflector (33).

8. A flat panel device as claimed in claim 7, wherein said stack (31, 33) has a different width for each color wavelength and wherein the stack for the different color wavelengths are positioned on top of each other, each stack extending such that the different color pixels are side-by-side.

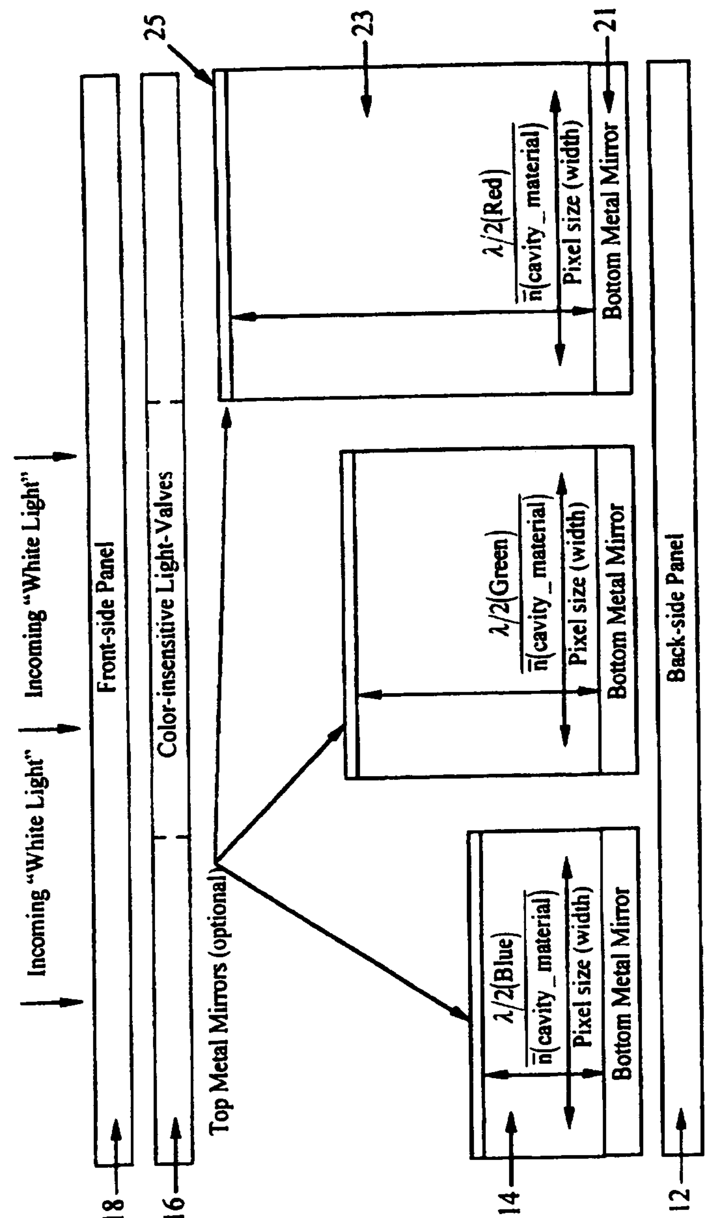
9. A flat panel device as claimed in claim 2, wherein the stack of microcavity material comprises a light absorbing layer (31) and a stack of co-extensive wavelength-selective photonic band-gap reflectors (35, 37, 39), each reflector having a different thickness .

10. A flat panel device as claimed in claim 9, wherein the light-valve means is integrated on top of said stack of wavelength-selective photonic band-gap reflectors and wherein said light-valve means is sensitive to the wavelength.

11. A flat panel device as claimed in either of claims 7 to 10, wherein each stack of wavelength –selective reflectors is made of a one-dimensional photonic band-gap material having reflection properties for a very narrow band of wavelength.

12. A flat panel device as claimed in either of the preceding claims, wherein the photonic wavelength filter structure is formed on amorphous, poly-crystalline or single crystal substrate.

13. A color addressing matrix panel as defined in any of the foregoing claims.



Incoming "White Light"
Incoming "White Light"
Front-side Panel
Color-insensitive Light-Valves
Top Metal Mirrors (optional)
λ/2(Red)
n̄(cavity_material)
Pixel size (width)
Bottom Metal Mirror
λ/2(Green)
n̄(cavity_material)
Pixel size (width)
Bottom Metal Mirror
λ/2(Blue)
n̄(cavity_material)
Pixel size (width)
Bottom Metal Mirror
Back-side Panel
25
23
21
18
16
14
12

Fig 1

Fig 2

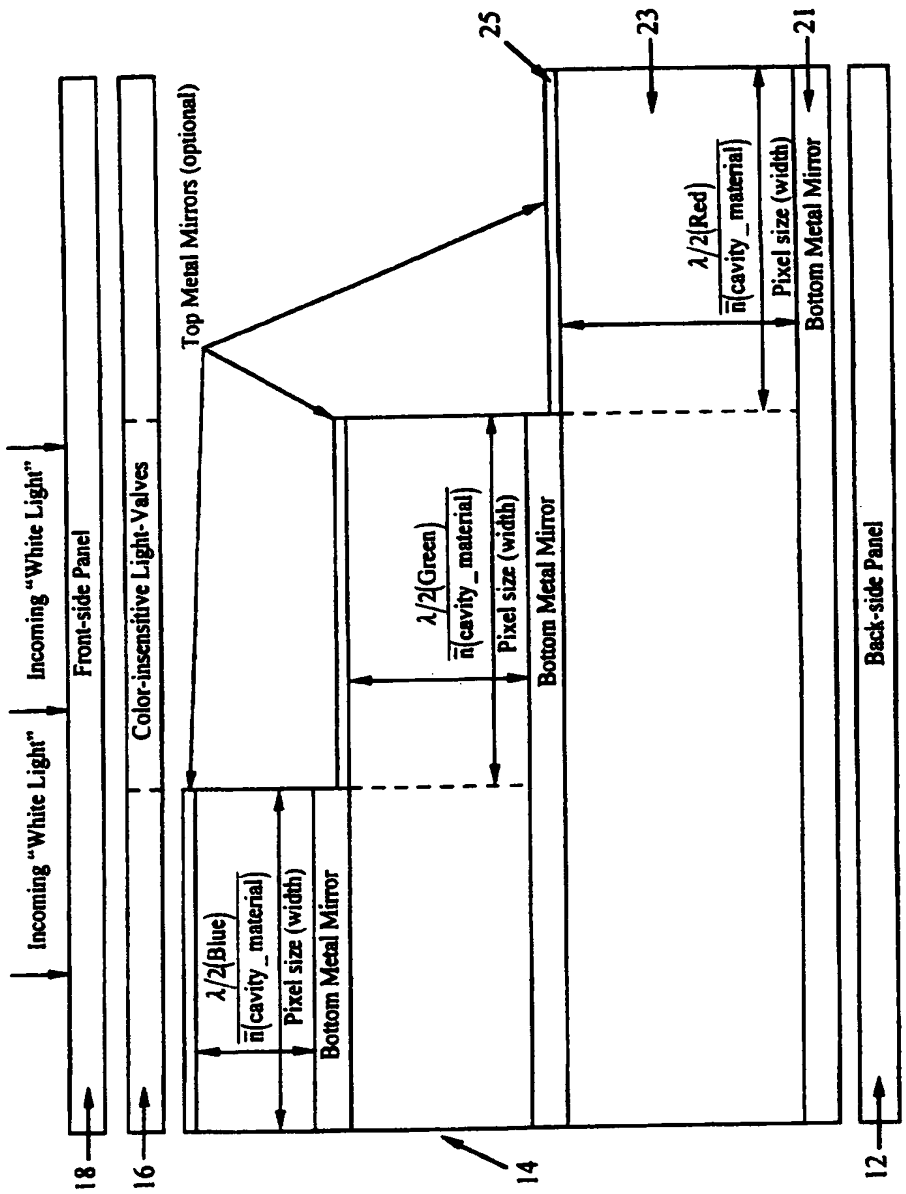


FIG.2

1. LUMIERE BLANCHE ENTRANTE
2. PANNEAU AVANT
3. MODULATEURS DE LUMIERE INSENSIBLES A LA LUMIERE
4. MIROIRS METALLIQUES SUPERIEURS (EVENTUELLEMENT)
5. $\underline{\lambda/2(\text{BLEU})}$ / n(CAVITE_MATIERE)
6. DIMENSION DE PIXEL (LARGEUR)
7. MIROIR METALLIQUE INFERIEUR
8. $\underline{\lambda/2(\text{VERT})}$ / n(CAVITE_MATIERE)
9. $\underline{\lambda/2(\text{ROUGE})}$ / n(CAVITE_MATIERE)
10. PANNEAU ARRIERE

Fig 2

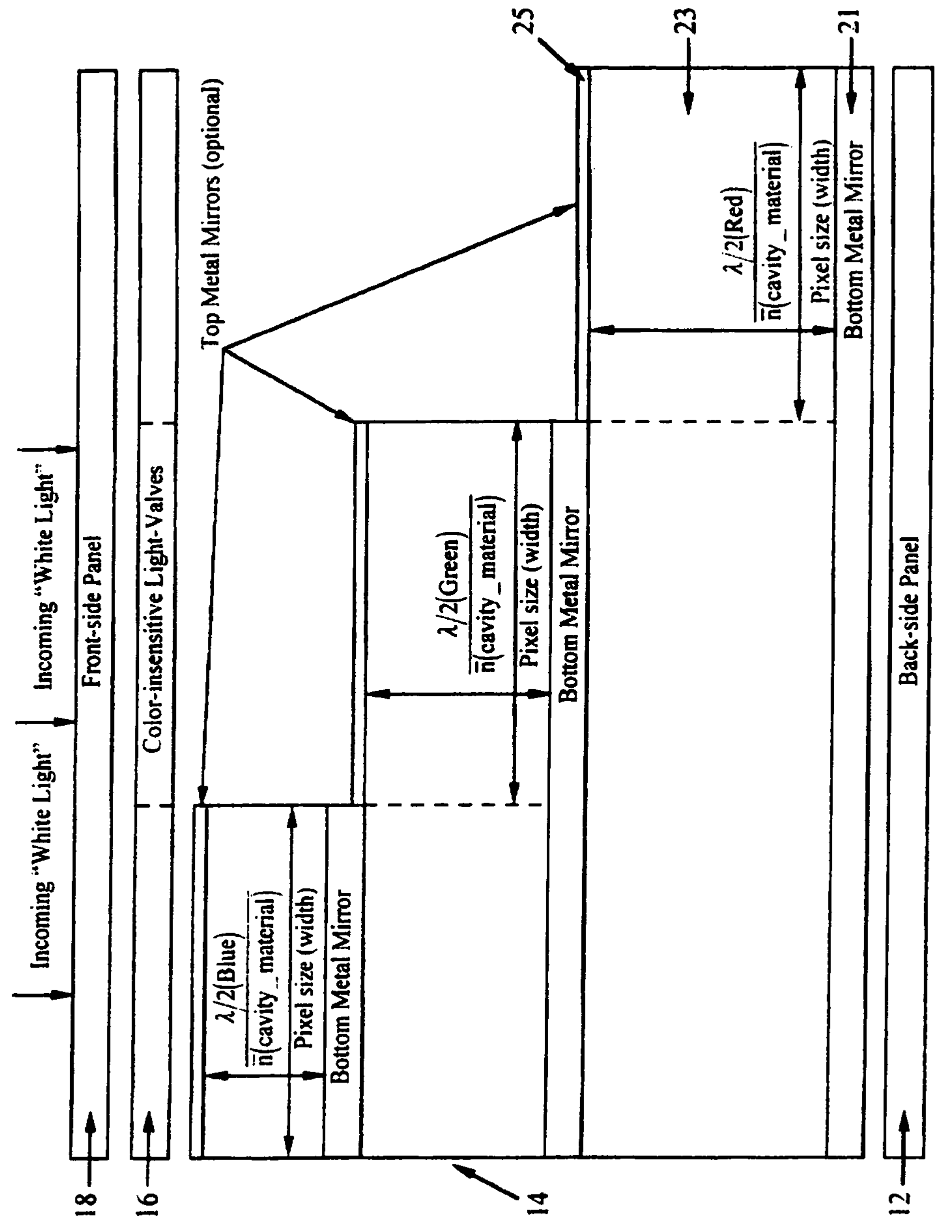
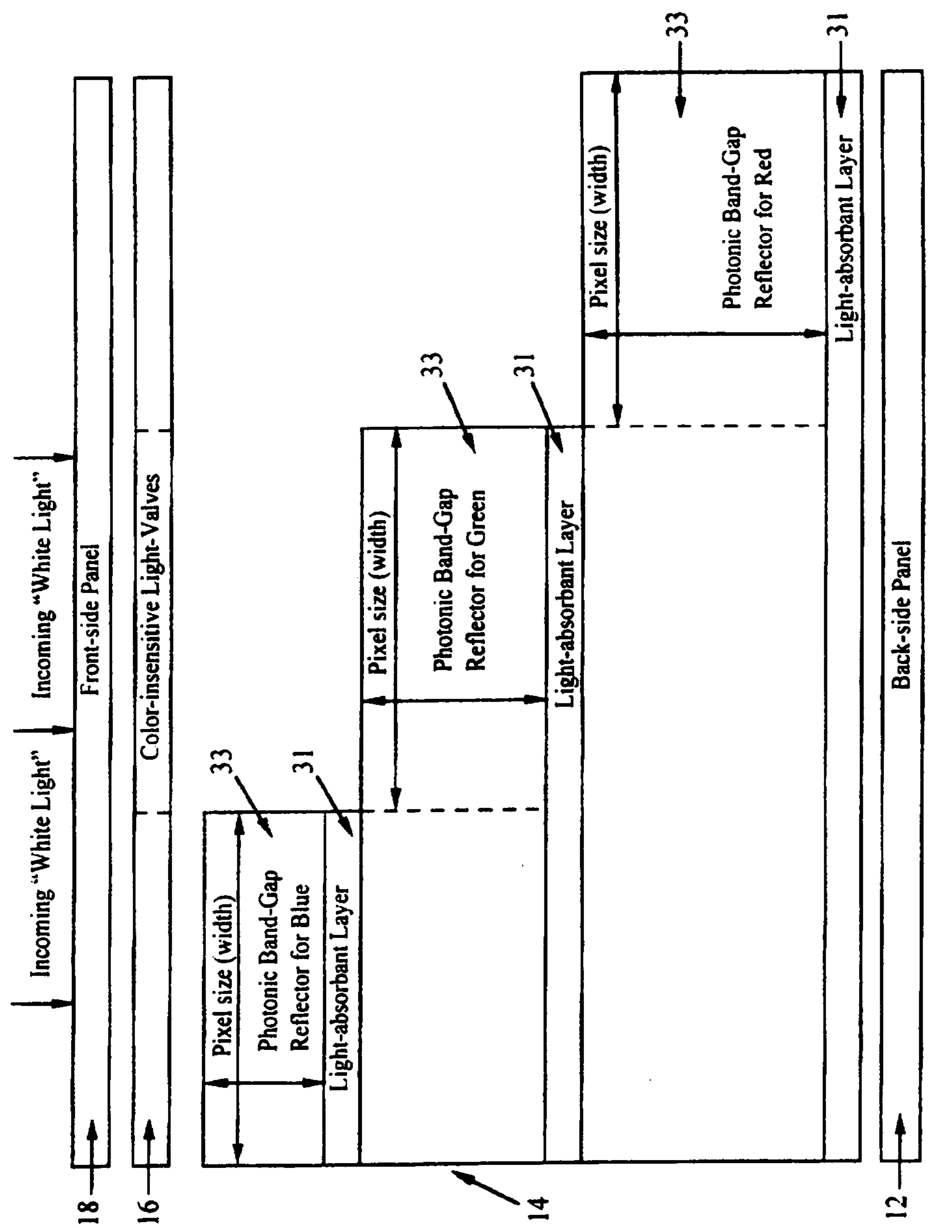

Incoming "White Light"
Incoming "White Light"
Front-side Panel
Color-insensitive Light-Valves
Top Metal Mirrors (optional)
λ/2(Blue)
n̄(cavity_material)
Pixel size (width)
Bottom Metal Mirror
λ/2(Green)
n̄(cavity_material)
Pixel size (width)
Bottom Metal Mirror
λ/2(Red)
n̄(cavity_material)
Pixel size (width)
Bottom Metal Mirror
Back-side Panel
25
23
21
18
16
14
12

Fig 3


Incoming "White Light"
Incoming "White Light"
Front-side Panel
Color-insensitive Light-Valves
Pixel size (width)
Photonic Band-Gap
Reflector for Blue
Light-absorbant Layer
Pixel size (width)
Photonic Band-Gap
Reflector for Green
Light-absorbant Layer
Pixel size (width)
Photonic Band-Gap
Reflector for Red
Light-absorbant Layer
Back-side Panel
33
31
33
31
33
31
18
16
14
12

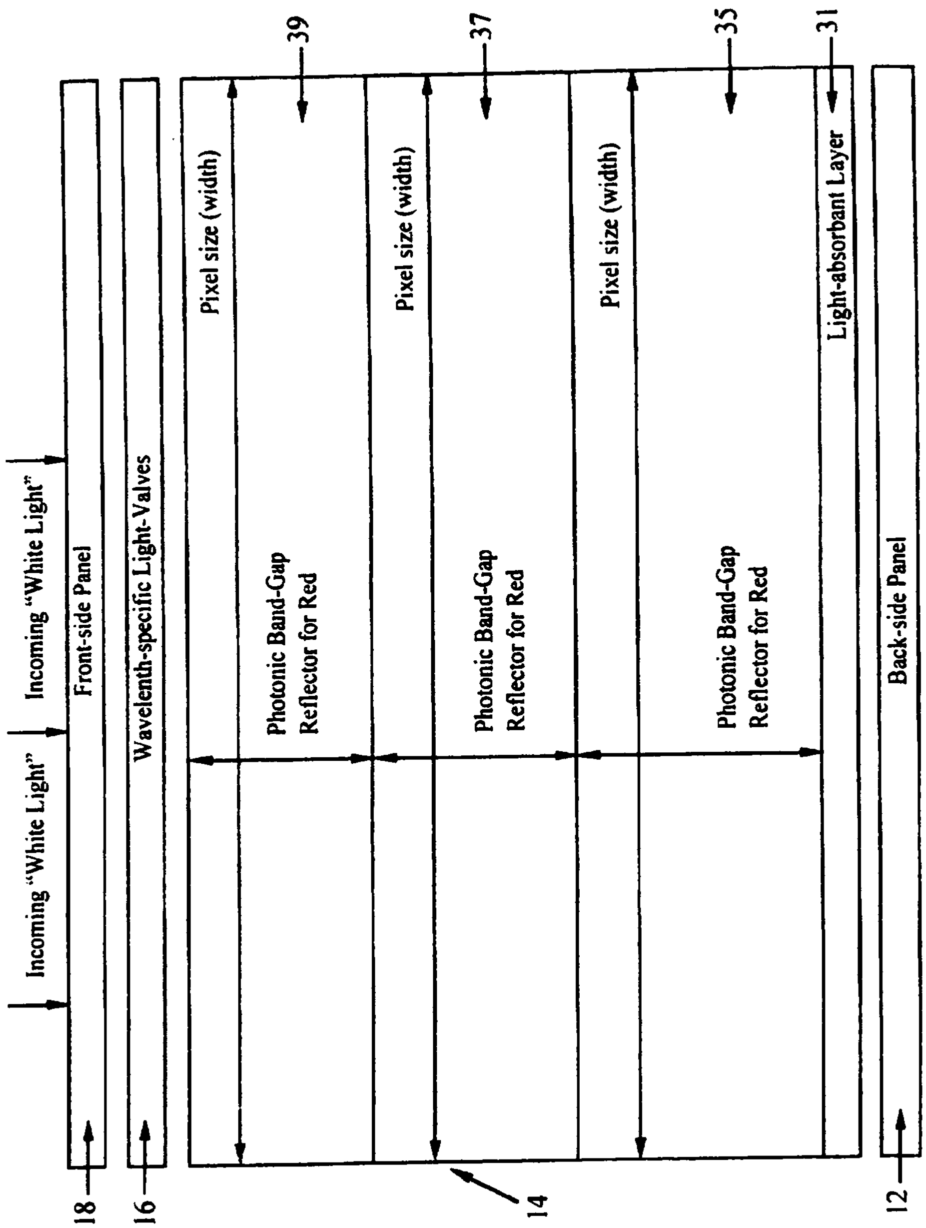

Incoming "White Light"
Incoming "White Light"
Front-side Panel
Wavelenth-specific Light-Valves
Pixel size (width)
Photonic Band-Gap
Reflector for Red
Pixel size (width)
Photonic Band-Gap
Reflector for Red
Pixel size (width)
Photonic Band-Gap
Reflector for Red
Light-absorbant Layer
Back-side Panel
39
37
35
31
18
16
14
12

Fig 4

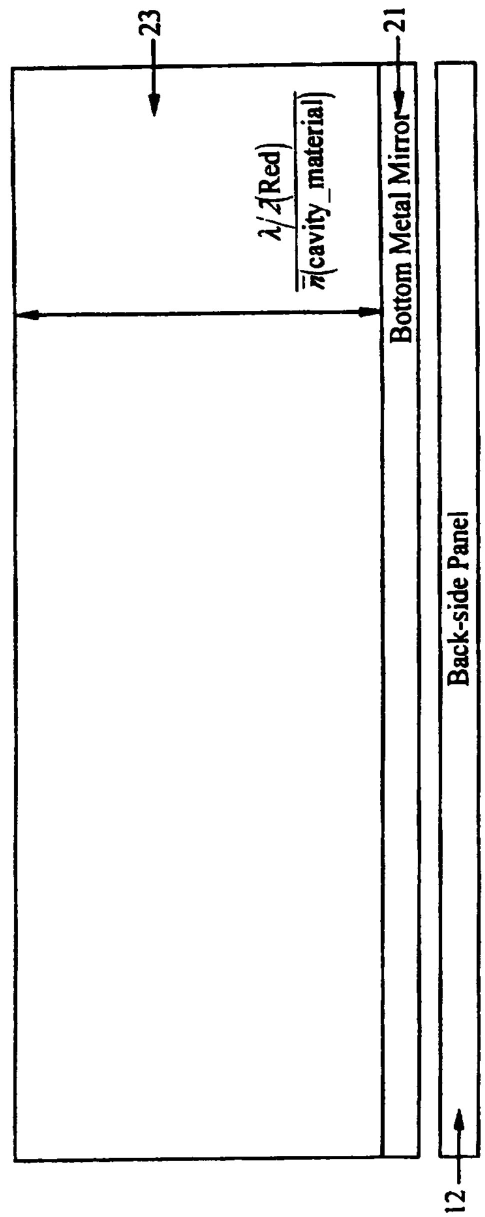
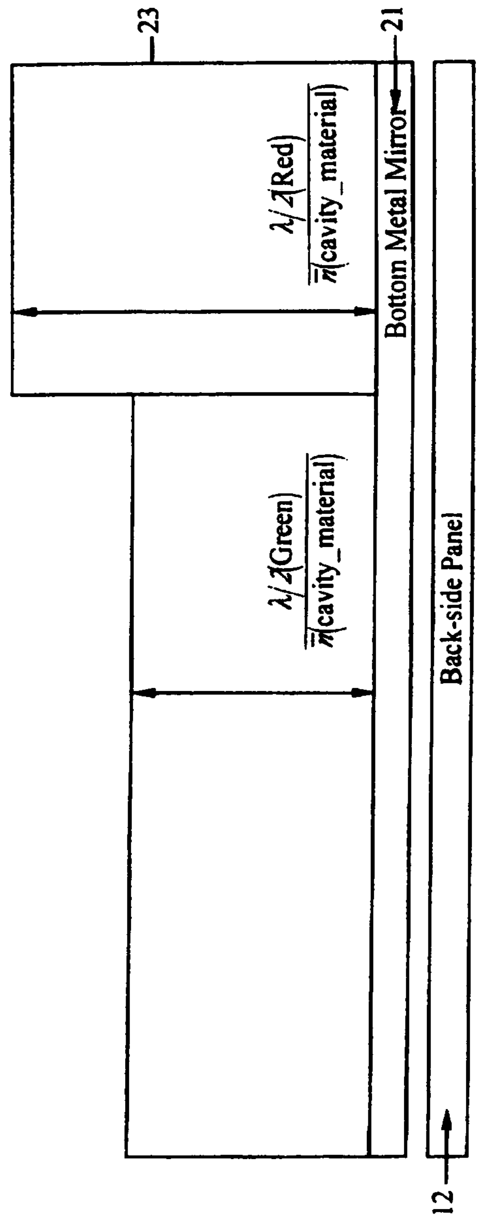

23
21
$\frac{\lambda/2(\text{Red})}{\bar{n}(\text{cavity\_material})}$
Bottom Metal Mirror
Back-side Panel
12

Fig 5A



23
21
λ/2(Red) / n(cavity_material)
Bottom Metal Mirror
λ/2(Green) / n(cavity_material)
Back-side Panel
12

Fig 5B

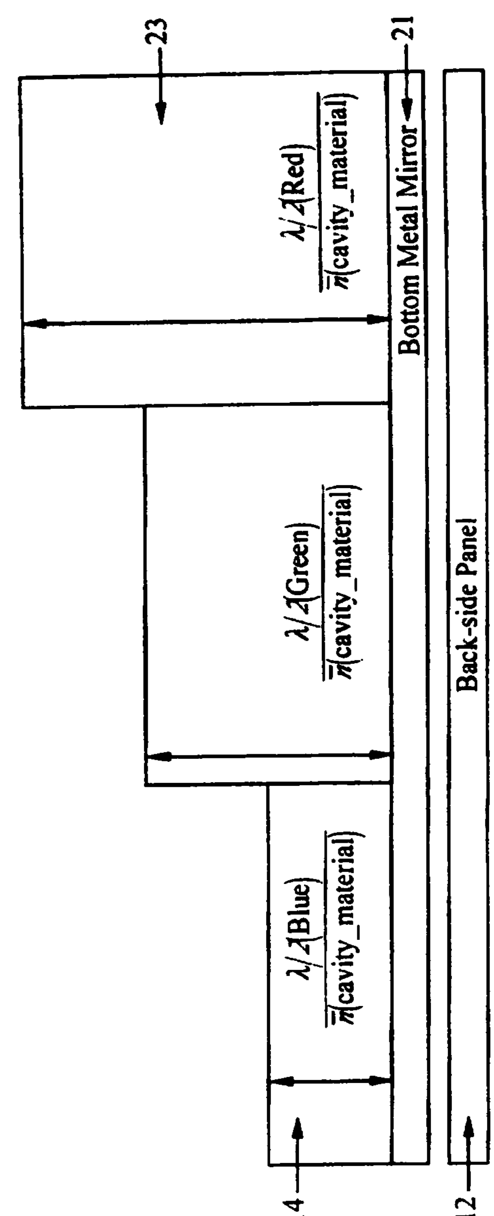
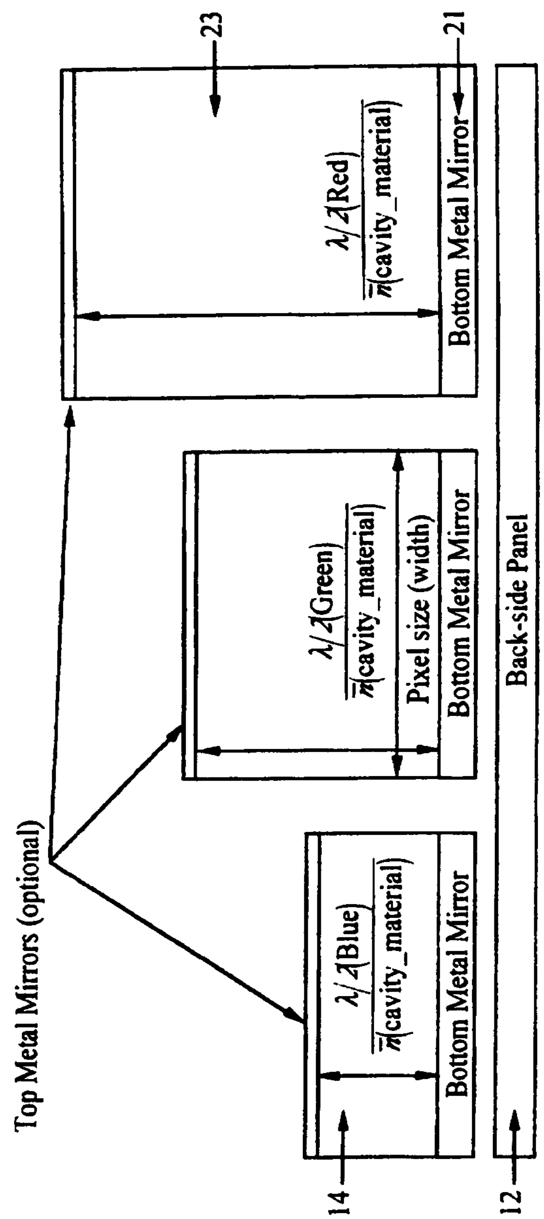

23
21
λ/2(Red) / n̄(cavity_material)
Bottom Metal Mirror
λ/2(Green) / n̄(cavity_material)
Back-side Panel
λ/2(Blue) / n̄(cavity_material)
14
12

Fig 5C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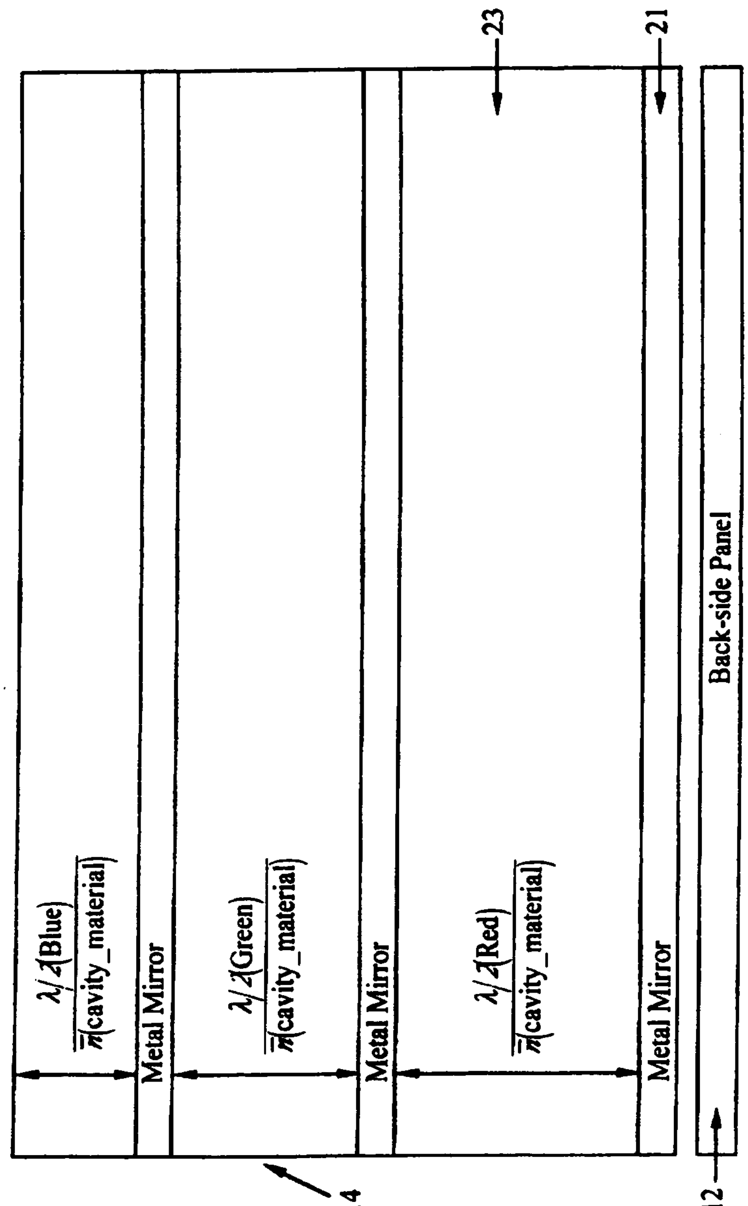
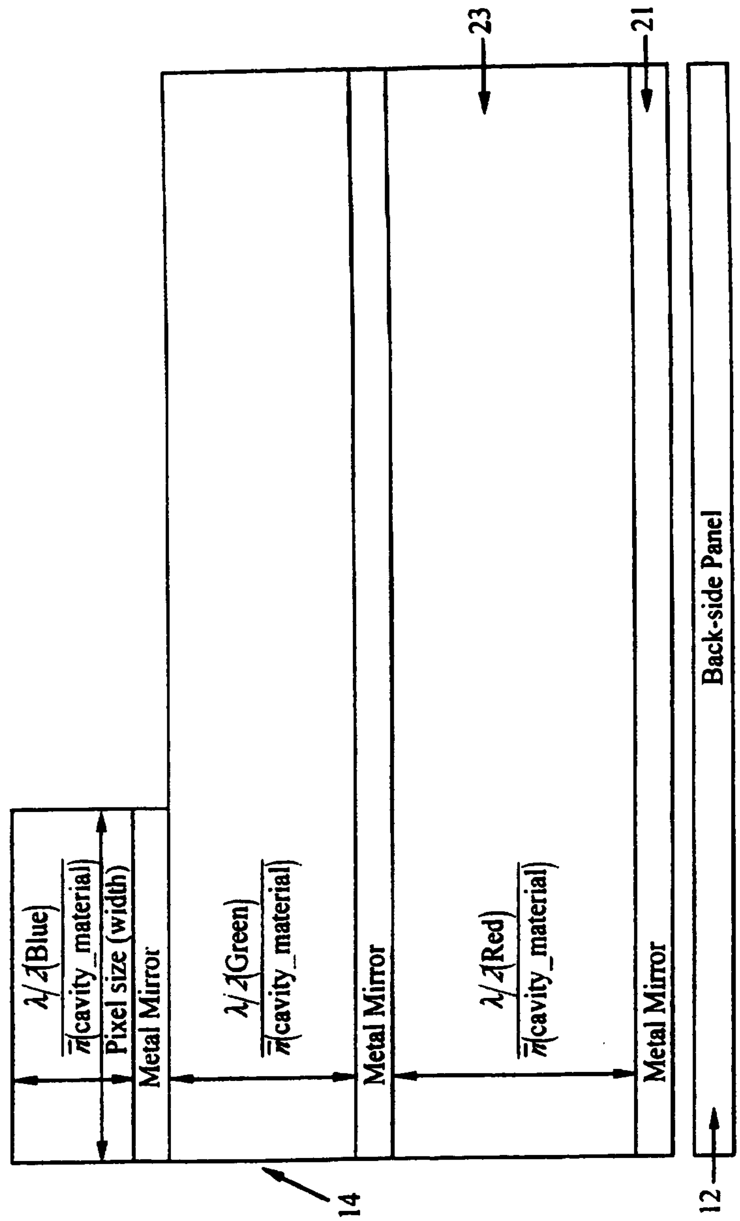
21
λ/2(Red)
n̄(cavity_material)
Bottom Metal Mirror
λ/2(Green)
n̄(cavity_material)
Pixel size (width)
Bottom Metal Mirror
Back-side Panel
Top Metal Mirrors (optional)
λ/2(Blue)
n̄(cavity_material)
Bottom Metal Mirror
14
12

Fig 5D

Fig 6A


23
21
λ/2(Blue) / n(cavity_material)
Metal Mirror
λ/2(Green) / n(cavity_material)
Metal Mirror
λ/2(Red) / n(cavity_material)
Metal Mirror
Back-side Panel
14
12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21
λ/2(Blue)
n(cavity_material)
Pixel size (width)
Metal Mirror
λ/2(Green)
n(cavity_material)
Metal Mirror
λ/2(Red)
n(cavity_material)
Metal Mirror
Back-side Panel
14
12

Fig 6B

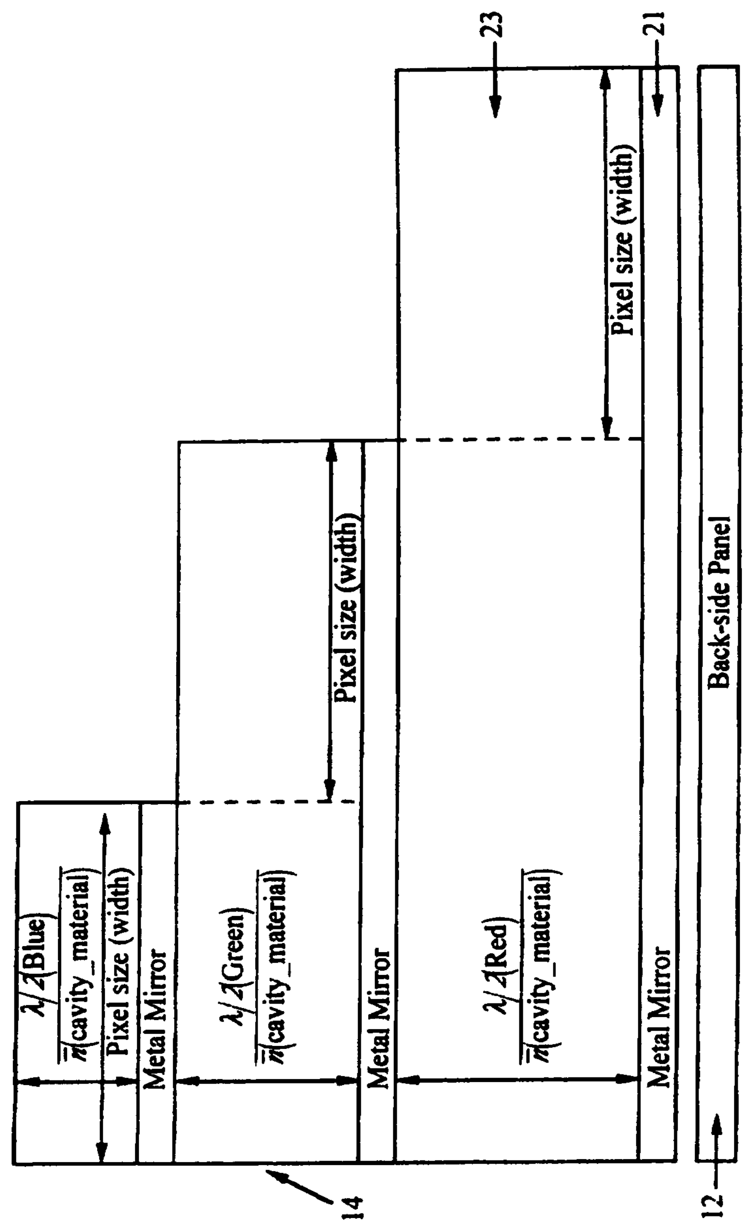
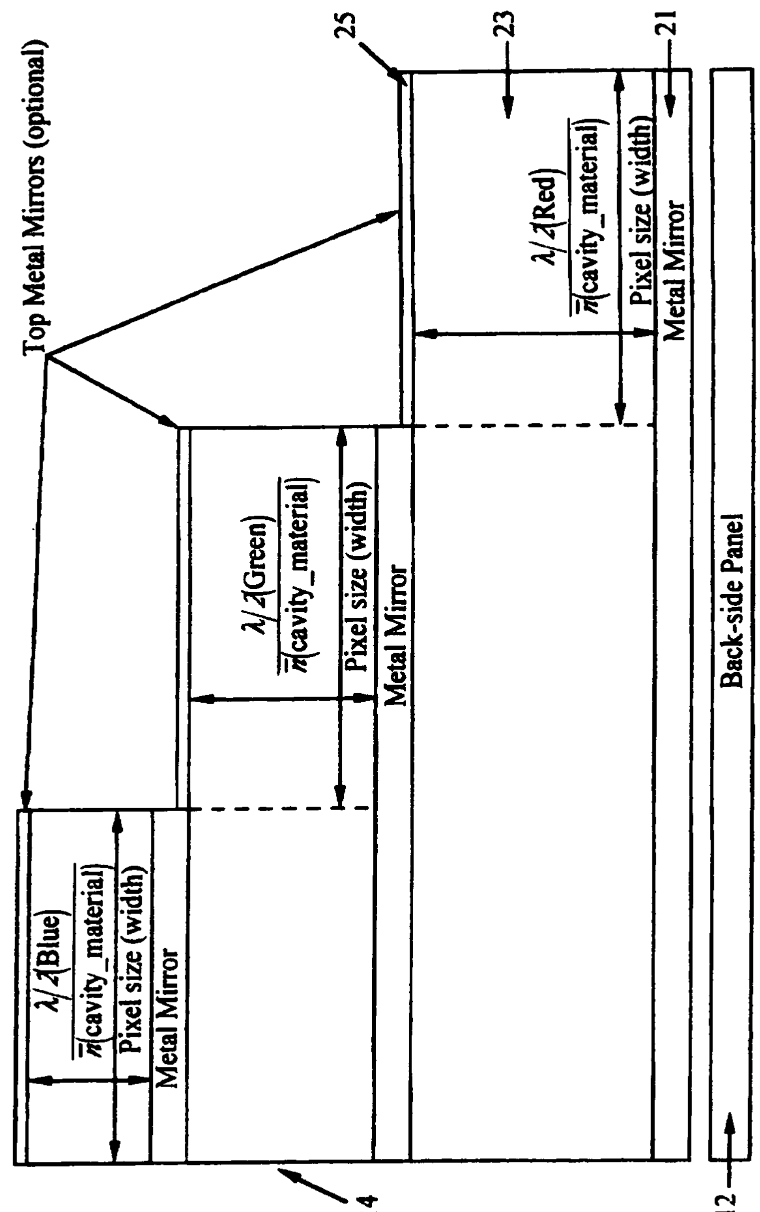

23
21
Pixel size (width)
Pixel size (width)
Back-side Panel
λ/2(Blue)
n̄(cavity_material)
Pixel size (width)
Metal Mirror
λ/2(Green)
n̄(cavity_material)
Metal Mirror
λ/2(Red)
n̄(cavity_material)
Metal Mirror
14
12

Fig 6C

Fig 6D


Top Metal Mirrors (optional)
25
23
21
λ/2(Red) / n(cavity_material)
Pixel size (width)
Metal Mirror
λ/2(Green) / n(cavity_material)
Pixel size (width)
Metal Mirror
λ/2(Blue) / n(cavity_material)
Pixel size (width)
Metal Mirror
Back-side Panel
14
12

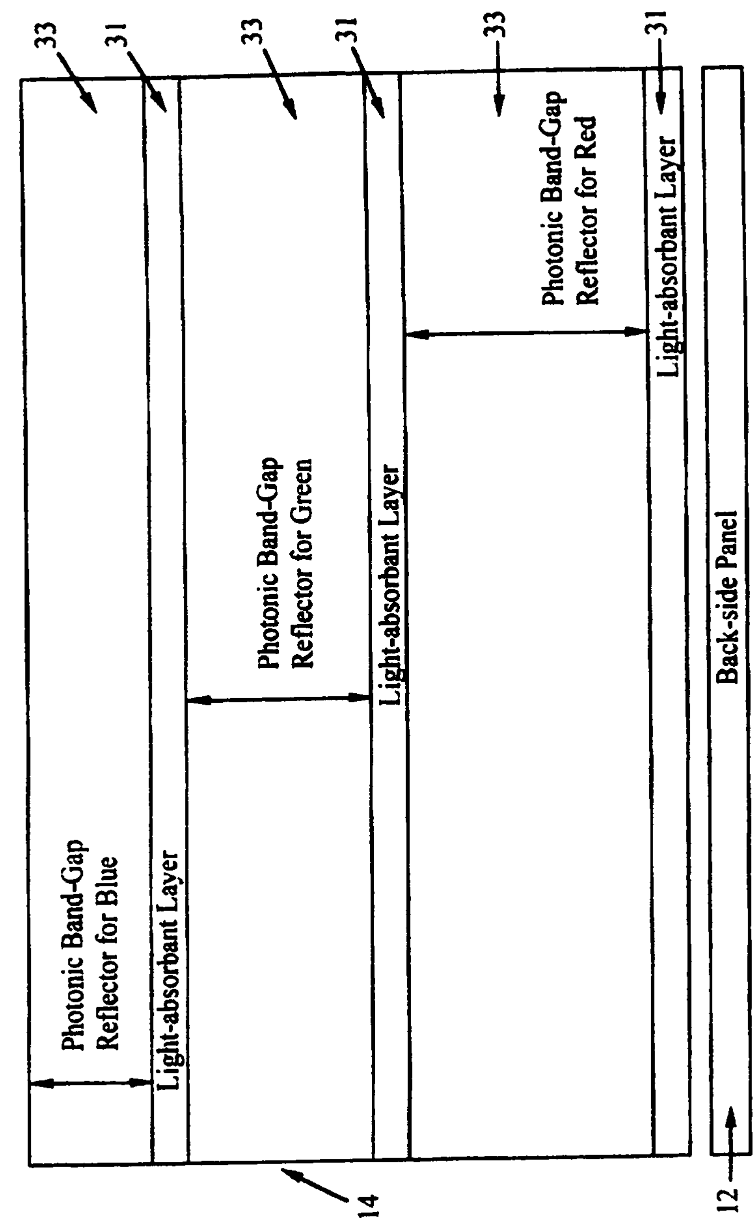

33
31
33
31
33
31
Photonic Band-Gap
Reflector for Blue
Light-absorbant Layer
Photonic Band-Gap
Reflector for Green
Light-absorbant Layer
Photonic Band-Gap
Reflector for Red
Light-absorbant Layer
Back-side Panel
14
12

Fig 7A

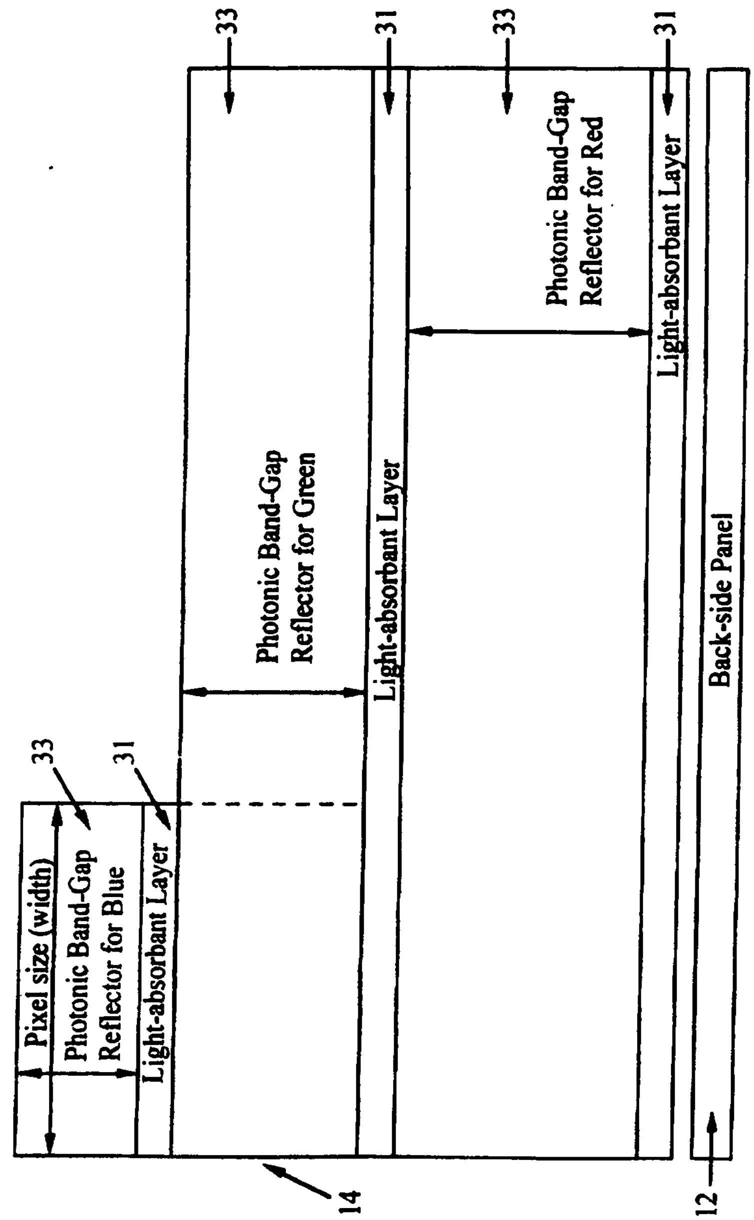
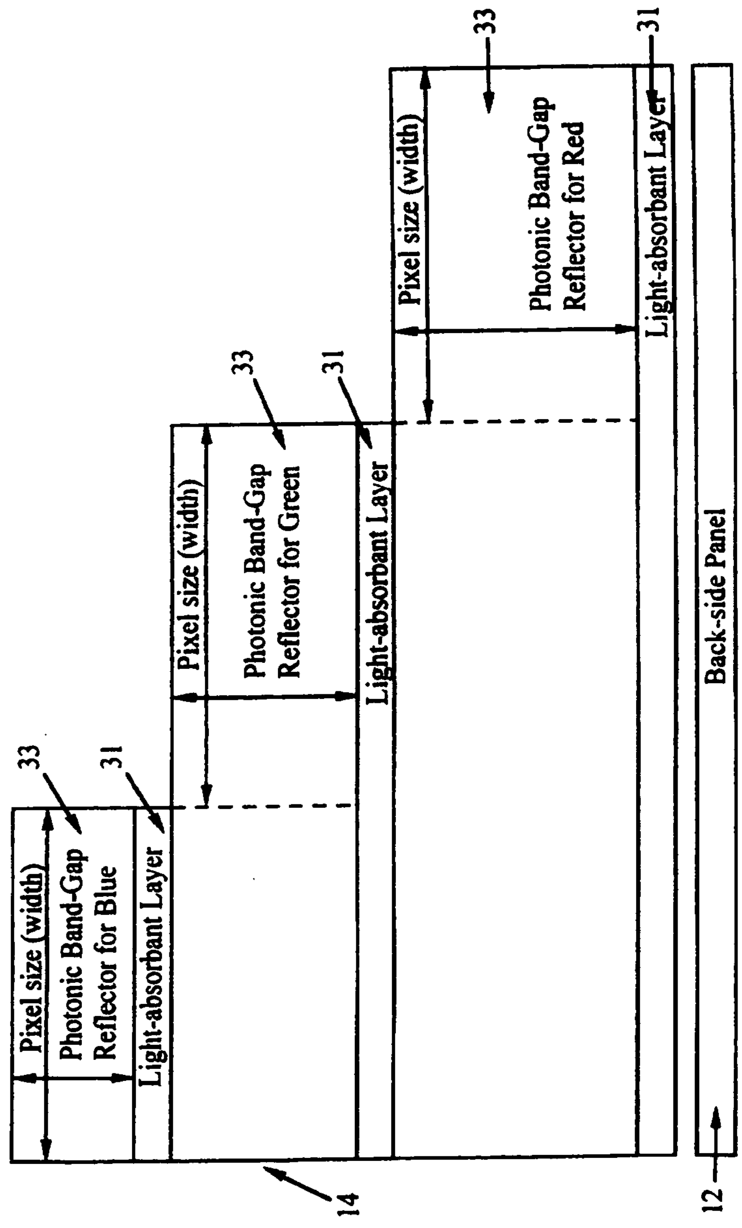

33
31
33
31
Photonic Band-Gap
Reflector for Red
Light-absorbant Layer
Photonic Band-Gap
Reflector for Green
Light-absorbant Layer
Back-side Panel
33
31
Pixel size (width)
Photonic Band-Gap
Reflector for Blue
Light-absorbant Layer
14
12

Fig 7B

Fig 7C


33
31
Pixel size (width)
Photonic Band-Gap Reflector for Red
Light-absorbant Layer
33
31
Pixel size (width)
Photonic Band-Gap Reflector for Green
Light-absorbant Layer
33
31
Pixel size (width)
Photonic Band-Gap Reflector for Blue
Light-absorbant Layer
Back-side Panel
14
12

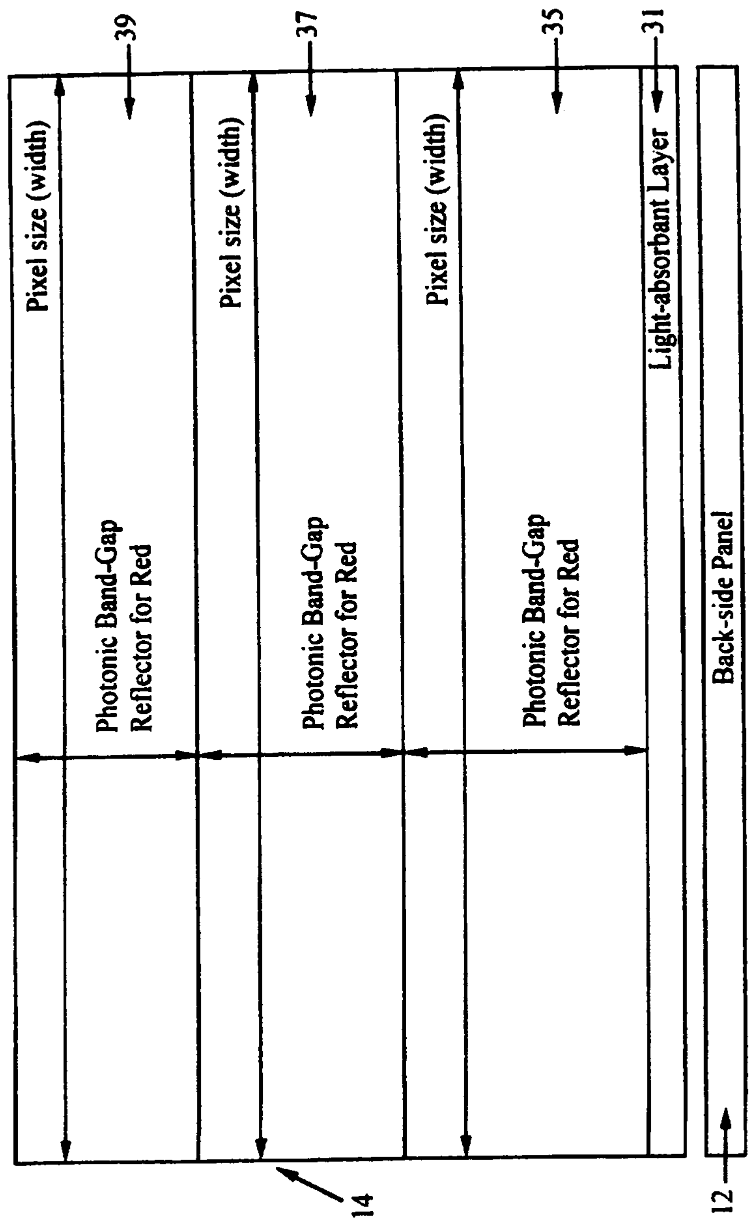

39
37
35
31
Pixel size (width)
Pixel size (width)
Pixel size (width)
Light-absorbant Layer
Photonic Band-Gap Reflector for Red
Photonic Band-Gap Reflector for Red
Photonic Band-Gap Reflector for Red
Back-side Panel
14
12

Fig 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 00/05588

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02F1/1335

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 95 17690 A (HONEYWELL INC) 29 June 1995 (1995-06-29) page 2, line 24 -page 3, line 09 page 4, line 25 -page 5, line 23; figure 3	1-6,13
X	US 5 804 919 A (JAFFE IRVING ET AL) 8 September 1998 (1998-09-08) column 6, line 26 - line 42 column 16, line 24 - line 36 column 20, line 31 - line 56	1,13
A	WU. S & AL: "Desing of a Reflective Color LCD Using Optical Interference Reflectors" ASIA DISPLAY OCT 16-18 , 1995, 1995, pages 929-930, XP002148248 hamamatsu Japan the whole document	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 September 2000	11/10/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Diot, P

INTERNATIONAL SEARCH REPORT

...ormation on patent family members

In ...al Application No
PCT/EP 00/05588

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9517690 A	29-06-1995	JP 8508114 T	27-08-1996
US 5804919 A	08-09-1998	AU 688780 B	19-03-1998
		AU 7403594 A	20-02-1995
		EP 0787352 A	06-08-1997
		JP 9501004 T	28-01-1997